

Physics monitor

Gravity waves

Apart from the reconciliation of the theory of gravitation with quantum physics, one of the few problems which remained in Einstein's monumental contribution to physics — the general theory of relativity — had been the detection of gravitational radiation.

Reports of the observation of gravity waves have come and gone over the years, but it is fitting that a confident new claim has been made in time for the year of the centenary of Einstein's birth (see page 3).

This latest observation ties in with the 'classical' experiments earlier this century which verified the general theory of relativity. This means that despite the numerous modifications which have been proposed over the years, the observed behaviour of gravity is exactly as predicted by Einstein in his original version of the theory.

In Einstein's formulation of general relativity, some solutions of the field equations have the properties of waves. These gravity waves travel at the speed of light and are similar in some respects to the electromagnetic radiation described by Maxwell's equations. They are produced by the acceleration of mass in much the same way as electromagnetic radiation results from the acceleration of electric charge.

However as far as we know, mass is always of the same sign, while electric charge can be either positive or negative. This means that gravitational radiation is detected through quadrupole rather than dipole effects.

Gravitational waves should produce minute tidal effects in objects in their path, and early attempts to detect the radiation concentrated on picking up this motion of the detecting equipment.

The expected magnitude of gravitational resonance in laboratory equipment is so small as to pose apparently insurmountable observational problems. For a metal bar one metre long, the induced movements due to gravity waves could be smaller than the diameter of a nucleon. In the face of such observational problems, some other way had to be found of detecting the waves.

Since they carry energy, gravity waves would sap the energy of an accelerated body, such as a continuously rotating binary star. Such a star was discovered in 1974 using the 300 m diameter fixed radio telescope at Arecibo, Puerto Rico. One of the rotating stars is a pulsar and, by careful measurements of its timing, astronomers were able to determine all the parameters of this rotating system.

This huge double star rotates with a period of about eight hours and pumps out gravitational radiation at a comparable rate to our sun emitting electromagnetic radiation, and its characteristics make it an ideal 'laboratory' for general relativists. Initial results confirmed general relativity effects hitherto seen only in planetary systems.

The continual loss of energy through gravitational radiation should affect the period of rotation of the system and a team, led by Joseph Taylor of the University of Massachusetts working at the Arecibo telescope, has been able to monitor these tiny variations using precision equipment.

The observed change in the orbital period is just one ten thousandth of a second per year. This is exactly the prediction of general relativity, and means that the study of gravitation has entered a new field of dynamical behaviour.

Hot spots discussed at Bonn

Is it reasonable to talk about a fraction of a particle or nucleus? Is there an 'up' and 'down' in such microscopic systems? A short time ago such questions appeared meaningless or, at least, highly speculative but this is changing.

By reformulating the questions — Can we localize excitations in a particle or nucleus? Is such a localization observable? — we begin to see positive answers from three independent experiments performed recently in Europe, Israel and Japan. The importance of this development for nuclear and particle physics is that it becomes feasible not only to follow the space-time evolution of a reaction but also to gain new information about nuclear matter (especially heat conductivity) which was not previously accessible to experiment.

The starting point of these developments were theoretical studies (particularly by R.M. Weiner) at the University of Marburg from 1974. New effects were predicted as a consequence of local excitations called 'hot spots'. These studies were supported in part by DESY, Los Alamos and Deutsche Forschungsgemeinschaft.

When two particles or nuclei have a glancing collision, it is expected that at first only their surfaces will be excited. Theoretical considerations suggest that this excitation will propagate rather slowly into the interior of the system and any emission of particles should therefore occur before the excitation has spread over the whole system. Since the excitation is only local, this emission takes place from a limited region which leads to a space asymmetry in the emission of particles.